ESTIMATING POTENTIAL BIOMASS OF SHELIKOF STRAITS BAIT HERRING HARVEST

By: Henry J. Yuen

Regional Information Report[1] No. 2H90-01
Alaska Department of Fish and Game
Division of Commercial Fisheries, Central Region
333 Raspberry Road
Anchorage, Alaska 99518-1599

January 1990

[1] Contribution 90-01 from the Lower Cook Inlet area office. The Regional Information Report Series was established in 1987 to provide an information access system for all unpublished divisional reports. These reports frequently serve diverse ad hoc informational purposes or archive basic uninterpreted data. To accommodate timely reporting of recently collected information, reports in this series may contain preliminary data; this information may be subsequently finalized and published in the formal literature. Consequently, these reports should not be cited without prior approval of the author or the Division of Commercial Fisheries.

AUTHORS

Henry J. Yuen is Region II Lower Cook Inlet Research Biologist for the Alaska Department of Fish and Game, Division of Commercial Fisheries, 333 Raspberry Road, Anchorage, AK 99518.

ACKNOWLEDGEMENTS

This report was presented at the Division of Commercial Fisheries Herring Workshop in Anchorage, January 29-31, 1990.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

A method to estimate the biomass of Pacific Herring (*Clupea harengus pallasi*) at a later age in the Kamishak sac roe fishery had they not been harvested in the Shelikof Straits bait fishery was presented. Input data were biomass and mean weight by age and an estimate of Kamishak natural mortality rates. The change in biomass from age 1 to any other age peaks at age 5. Each tonne of age 1 herring biomass was projected to grow to 2.87 tonnes at age 5, after the effects of natural mortality were accounted for.

KEY WORDS: bait fishery, *Clupea harengus pallasi*, herring, forecast, Lower Cook Inlet, mortality, sac roe fishery, Shelikof Straits.

INTRODUCTION

The range of the Lower Cook Inlet stock of Pacific herring (*Clupea harengus pallasi*) is such that they are fished twice annually, once in the spring during the Kamishak sac roe fishery and later in the winter as the Shelikof Straits bait fishery (Figure 1). The age composition of the two fisheries, however, are very different (Figure 2). The herring in the sac roe fishery are comprised of mature and spawning adults greater than age 3 while those in the bait fishery include juveniles as young as age 1. The following question is often asked of the fishery managers: what would the biomass of the herring in the bait fishery be if they were not harvested, but allowed to recruit into the sac roe fishery?

The objective of this report is to present a simple method of calculating the answer to that question. The methods section focuses on the estimation of natural mortality rates from the existing Kamishak data while the results section presents a tabular means of predicting future biomass from a present biomass.

METHODS

The forecast presented in this report is for herring biomass at a later age assuming that they were not harvested in the bait fishery. The model requires data on (1) abundance by age in the bait harvest, (2) mean weight by age in the bait harvest, and (3) age-specific natural mortality.

Bait Harvest Estimates

The Shelikof straits bait harvest biomass and mean weight by age can be obtained from Larry Malloy (personal communications) or from the Kodiak Management Area Finfish Annual Management Report. Biomass has to be converted to abundance by age. This is simply

$$N_{b,i} = B_i \ / \ W_i,$$

where N_b = bait fishery harvest abundance,
B = biomass,
W = mean weight at the time of the bait fishery harvest, and
i = age.

If the harvest was reported by separate fishing periods, then a total abundance will have to be calculated from the sum of the period abundances.

Mortality Function

Herring instantaneous total mortality rates are typically referred to in the literature as Z. That is,

$$Z_{i-1} = -\ln(N_{s,i,t} / N_{s,i-1,t-1}),$$

where N_s = total abundance (catch + escapement)
i = age, and
t = year.

Z as defined above is the sum of M (natural mortality) and F (fishing mortality) because N in the demominator includes catch. That is, both M and F is assumed to occur simultaneously over the time period t. In this report, Z′ will be defined as Z without the effects of F as Z′ is calculated after the fishery has occurred (Yuen and Schroeder 1989). This approach can justified as the sac roe fishery occurs over a very short period of time, once a year, leaving natural mortality to occur the remaining portion of the year. Thus,

$$Z'_{i-1} = -\ln(N_{s,i,t} / S_{i-1,t-1}),$$

where S = unharvested spawning abundance (i.e. escapement).

However, both Z and Z′ as defined above include the effects of recruitment (R) into the spawning population for the younger age groups (e.g. age < 7). In other words, Z′ is the instantaneous rate of change in apparent annual abundance as a result of the concurrent effects of M and R on the unharvested spawning biomass (i.e. escapement). If M > R, such that the population appeared to be decreasing in size, Z′ would be positive and vice versa (Figure 3).

If recruitment was not present, then

$$M_{i-1} = -\ln(N_{s,i,t} / S_{i-1,t-1}) = Z'_{i-1},$$

because $N_{s,i,t} < S_{i-1,t-1}$. Within the Kamishak herring data set, there were many instances where a positive Z′ was calculated among the younger age groups (the entire data set can be found in Yuen and Schroeder (1989). Ages 3 through 7 are not usually considered to be fully recruited and negative values of Z′ were expected. A common explanation for this type of anomaly would be that gross errors had occurred in making the biomass estimates. Another possibility would be extremely poor and insignificant recruitment had actually occurred. In the latter scenario, age specific values of M could be estimated from a power curve fitted through all positive values of M (Figure 4, $r^2 = 0.35$, d.f. = 22), where

$$M_{i-1} = -0.046177\ (1.225001^{age}{}_{i-1}).$$

As an alternative, a Z′ curve was also calculated to determine if the M and Z′ curve were the same among the fully recruited age groups. In Yuen and Schroeder (1988), the performance of several Z′ models for Kamishak herring were compared. The sum of deviations in back calculated biomass (squared) was used as a measure of model performance, that is, observed total biomass minus estimated total biomass. Biomass was back calculated with a cohort analysis where we estimate backwards in time the numbers of fish in the year t-1 from the number of fish in year t and Z′. The median rate as a model was found to outperform mean rates, regression of rate on age, and catch curve analysis in terms of the sum of back calculated biomass deviations squared.

Therefore, the median of the negative Z′ values was used to form a 'curve' through the observed age 6 and younger Z′ values. Age 6 is the age at the time of spawning as opposed to the age during the year of the forecast. The only exceptions were that 1978 data were not used to derive the median age 5 value and the 1985, 86, and 88 data were not used in the median age 6 value (Table 1). The trend of this 'curve' was a decreasing rate of change with age. Not using those data forced the curve upwards toward full recruitment at age 7. Nevertheless, a dip can still be seen in the curve at age 5 and 6 (Figure 3). Extrapolating from this 'curve' for ages greater than 6 would underestimate the observed values of Z′ as we are assuming either a constant or accelerating rate of change in Z′ for the fully recruited herring.

Thus, for ages 7 and older, a regression line was fit through the positive Z′ values (r^2 = 0.50, d.f. = 19), i.e.

$$Z'_{i-1} = -1.01477 + 0.149636\ age_{i-1}.$$

Because the rate of change in the observed Z′ between the ages of 2 and 4 is large, using the ages 7 and older model to extrapolate to age 3-6 would greatly overestimate Z′ (Figure 3).

For the fully recruited age groups, one would expect M and Z′ to be identical. However, the estimates of M and Z′ do not agree. M for the older age classes appear to be underestimated by the power curve fit (Figure 5) and Z′ for ages 10 and older was used instead (Table 1 and Figure 6).

Biomass Forecast

The forecast of biomass is the product of future numbers of fish (predicted from the bait harvest abundance plus natural mortality) and future mean weight. Future mean weight was assumed to be the same as the age specific mean weight found in the bait harvest (Table 1). A model of future mean weights could also have been used instead. Meanwhile,

$$B_t = \quad (N_{s,i,t}\ W_i);$$

where $N_{s,i,t} = N_{b,i-1,t-1}\ e^{-(M_{i-1})}$, and

$$e = 2.7183.$$

RESULTS

Using the 1989-90 winter bait harvest as an example, if the 81,000 age 1 herring were not harvested, they are expected to decrease in abundance to 77,000 age 2 individuals a year later, to 73,000 age 3 individuals in 1991, etc. (Table 2 and

Figure 7). However, mean weight will increase with time (Table 3 and Figure 8). The effect of the two phenomena is an increase in biomass with a peak at age 5. Biomass will then decrease to zero with the decay of the population (Table 3 and Figure 9). Conversion factors to calculate future biomass from the present bait harvest biomass by age is presented in Table 4.

DISCUSSION

The natural mortality rates estimated from all of the positive Z′ values regardless of age appear to be reasonable. M is nonconstant for all ages, consistent with Vetter's (1988) arguments. Vetter goes on (citing Smith's (1985) study of the northern anchovy) to describe a pattern of mortality rates for clupeoids: while extremely high during the egg and larval stage, a much lower rate of mortality beginning with age 1 and increasing with age. The pattern of M values estimated in this report is also consistent with that scenario.

A reservation could be made regarding the assumption that herring recruitment, which takes places over a period of years, was a process that could be interrupted such that year class strength would appear to oscillate over time. It is from those interruptions that an estimate of M for the younger age groups was derived. There is some support for interruptions of this nature as Lapin and Pokhilyuk (1897) have felt that the White Sea herring (*Clupea pallasi marisalbi*) would delay spawning or even not spawn in the current season if gonad and body growth rates were poor. However, it is very difficult to ascertain if an interruption had occurred or if there were a lot of noise in the annual biomass and age composition estimates. The Kamishak herring data base, unfortunately is not large enough at this time to test Lapin and Pokhilyuk's hypothesis.

The mortality schedules for two adjacent herring stocks are presented in Table 5. While there is some similarity between the Kamishak and Togiak schedules, there is none with those estimated for Prince William Sound.

LITERATURE CITED

Brannian, L.K. 1989. Forecast of the Pacific herring biomass in Prince William Sound, 1989. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A89-01. Anchorage.

Lapin, Y.E. and V.V. Pokhilyuk. 1987. Biological characteristics of the spawning groups of White Sea herring, *Clupea pallasi marisalbi*, related to fecundity. Journal of Ichthyology. No. 2, pp. 248-253. Translation in Scripta Technica, Inc. ISSN0032-9452/87/0003-0135.

Rowell, K.A. and L.K. Brannian. 1989. Forecast of the Pacific herring biomass in Togiak District, Bristol Bay, 1989. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2D89-11. Anchorage.

Smith, P.E. 1985. Year-class strength and survival of 0-group clupeoids. Can. J. Fish. Aquat. Sci. 42:69-82.

Vetter, E.F. 1988. Estimation of natural mortality in fish stocks: a review. Fishery Bulletin 86:25-43.

Yuen, H.J. and T.R. Schroeder 1988. Summary of the 1989 Kamishak herring stock projection. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2H88-9. Homer.

Yuen, H.J. and T.R. Schroeder 1989. Methods of the 1990 Kamishak herring stock projection. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2H89-11. Homer.

Table 1. Age specific estimates of M for Kamishak Herring and mean weights from Shelikof Straits bait harvest, 1989.

age	mortality Z	1989 food/bait mean wt (g)
1	0.057	36
2	0.069	87
3	0.085	124
4	0.104	163
5	0.127	200
6	0.156	222
7	0.191	251
8	0.234	271
9	0.287	280
10	0.482	282
11	0.631	315
12	0.781	
13	0.931	

Table 2. Example of declining abundance (x 1,000) over a 13 year period beginning with 1989.

	year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
	age	1	2	3	4	5	6	7	8	9	10	11	12	13
	1	81	77	72	66	59	52	45	37	29	22	14	7	3
	2	228	212	195	176	155	133	109	87	65	40	21	10	
	3	192	177	159	140	120	99	78	59	36	19	9		
	4	607	547	482	412	340	269	202	125	66	30			
	5	495	436	373	308	244	183	113	60	28				
	6	37	31	26	21	15	10	5	2					
age	7	82	67	53	40	25	13	6						
	8	72	57	43	26	14	6							
	9	76	57	35	19	9								
	10	25	15	8	4									
	11	55	29	13										
	12	0	0											
	13	0												
	total	1,950	1,706	1,460	1,212	981	766	559	370	225	112	44	17	3

Table 3. Example of biomass (tonnes) change over a 13 year period beginning with 1989 and using bait harvest mean weights.

	year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
	age	1	2	3	4	5	6	7	8	9	10	11	12	13
	1	2.9	6.7	8.9	10.7	11.9	11.6	11.2	10.0	8.2	6.2	4.3		
	2	19.8	26.3	31.8	35.3	34.3	33.3	29.7	24.2	18.4	12.6			
	3	23.8	28.8	31.9	31.1	30.2	26.9	21.9	16.6	11.5				
	4	98.8	109.6	106.7	103.6	92.2	75.3	57.1	39.3					
	5	99.3	96.7	93.9	83.5	68.2	51.7	35.6						
	6	8.1	7.9	7.0	5.7	4.3	3.0							
age	7	20.5	18.3	14.9	11.3	7.8								
	8	19.6	16.0	12.1	8.3									
	9	21.1	16.0	11.0										
	10	7.0	4.8											
	11	17.4												
	12													
	13													
	total	338	331	318	290	249	202	156	90	38	19	4	0	0

Table 4. Conversion factors to forecast change in biomass over time by age.

		to sac roe age									
		2	3	4	5	6	7	8	9	10	11
from food/bait age	1	2.32	3.07	3.71	4.11	4.01	3.89	3.46	2.83	2.14	1.48
	2		1.32	1.60	1.78	1.73	1.68	1.49	1.22	0.93	0.64
	3			1.21	1.34	1.31	1.27	1.13	0.92	0.70	0.48
	4				1.11	1.08	1.05	0.93	0.76	0.58	0.40
	5					0.97	0.95	0.84	0.69	0.52	0.36
	6						0.97	0.86	0.71	0.53	0.37
	7							0.89	0.73	0.55	0.38
	8								0.82	0.62	0.43
	9									0.76	0.52
	10										0.69

Table 5. Estimates of natural mortality from Prince William Sound, Kamishak Bay, and Togiak.

age	PWS[a]	Kamishak	Togiak[b]
1		0.057	
2	0.343	0.069	
3	0.343	0.085	0.103
4	0.343	0.104	0.103
5	0.343	0.127	0.103
6	0.344	0.156	0.103
7	0.365	0.191	0.226
8	0.450	0.234	0.348
9	0.667	0.287	0.471
10	1.108	0.482	0.593
11	1.887	0.631	0.715
12	3.139	0.781	0.838
13	5.200	0.931	0.960

[a] Brannian 1989
[b] Rowell and Brannian 1989

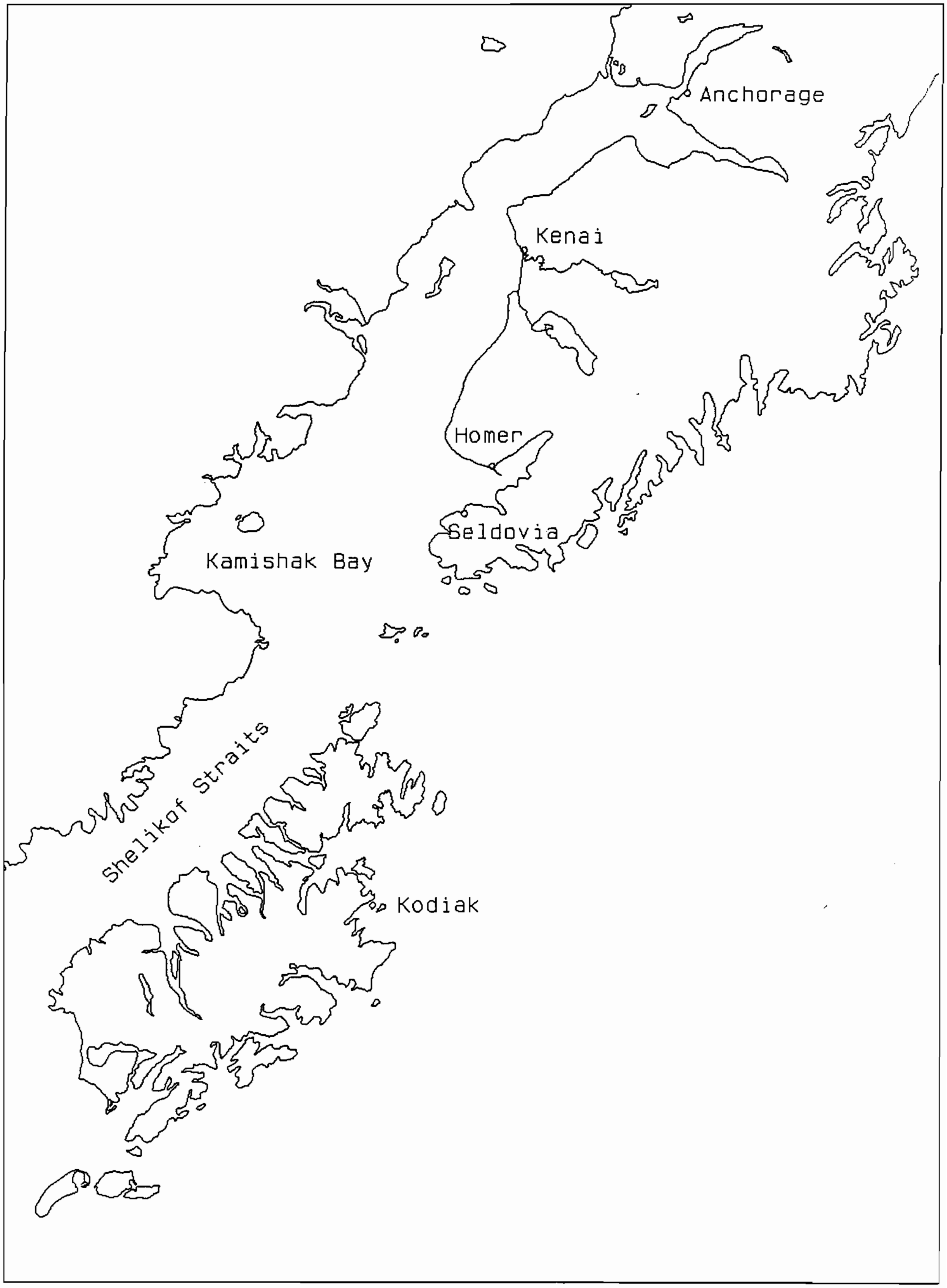

Figure 1. Kamishak Bay and Shelikof Straits

ACE 6231915

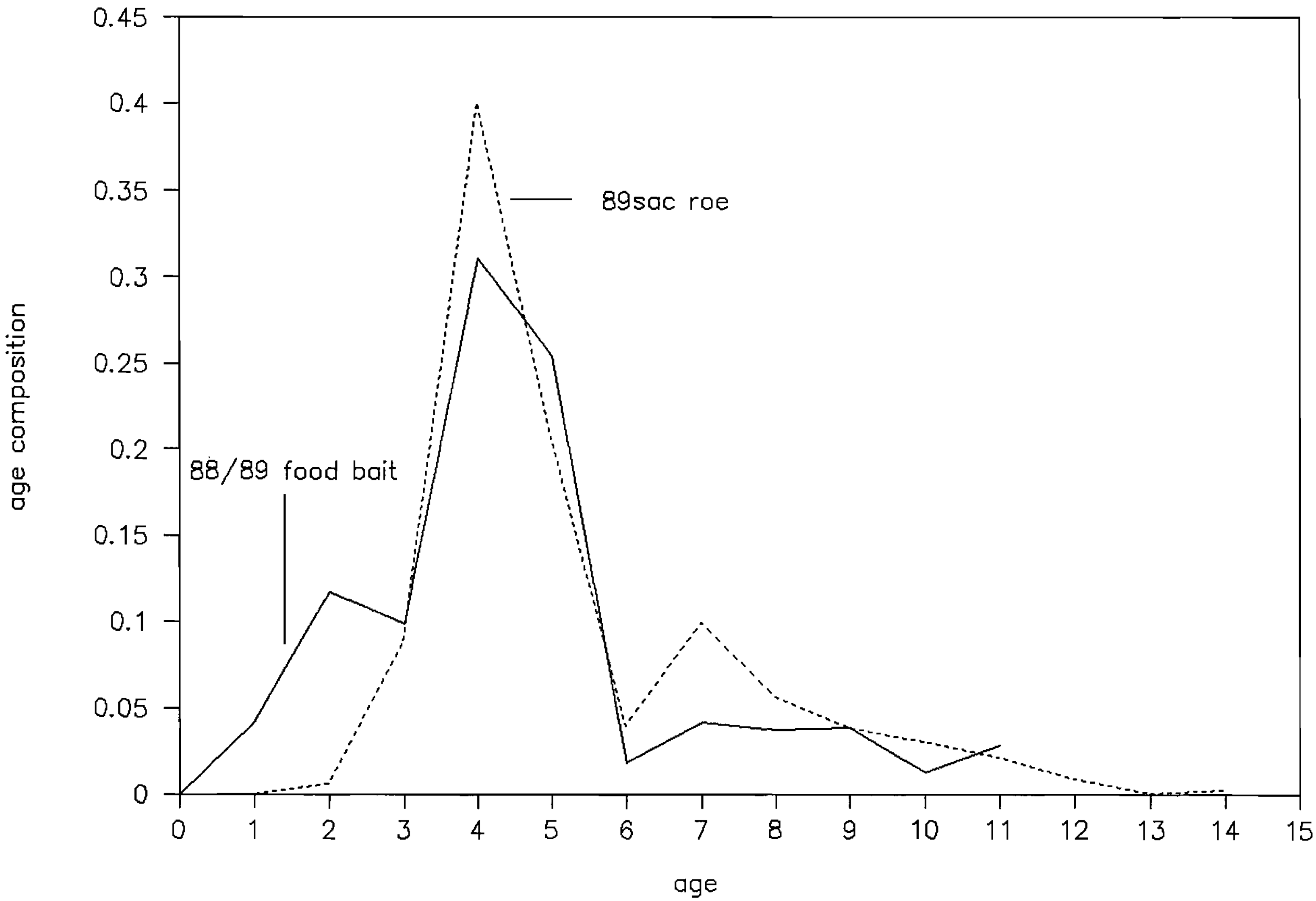

Figure 2. Comparison of sac roe and bait age composition, 1989.

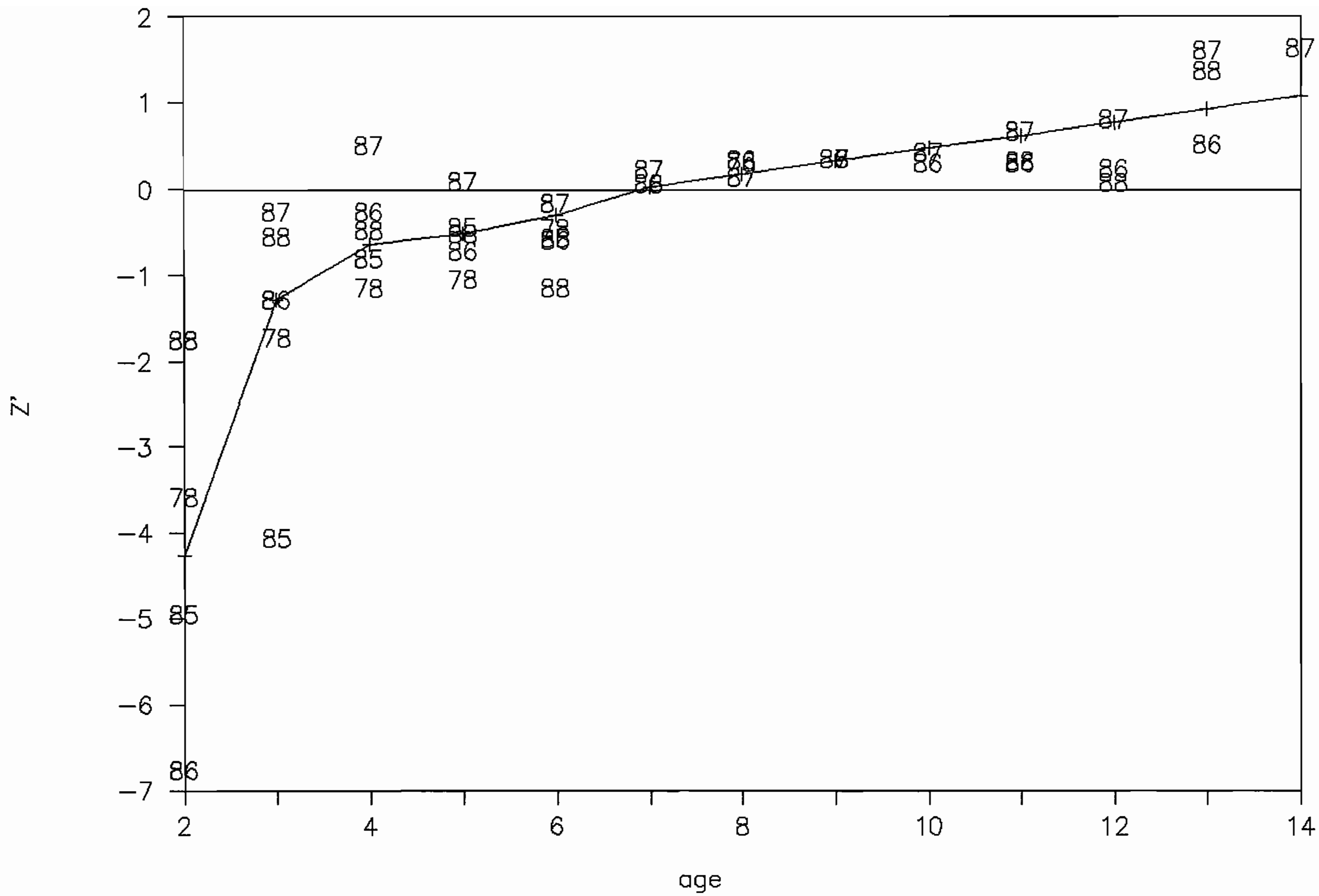

Figure 3. Age specific Z' from median (age<7) and regression (age>6) methods.

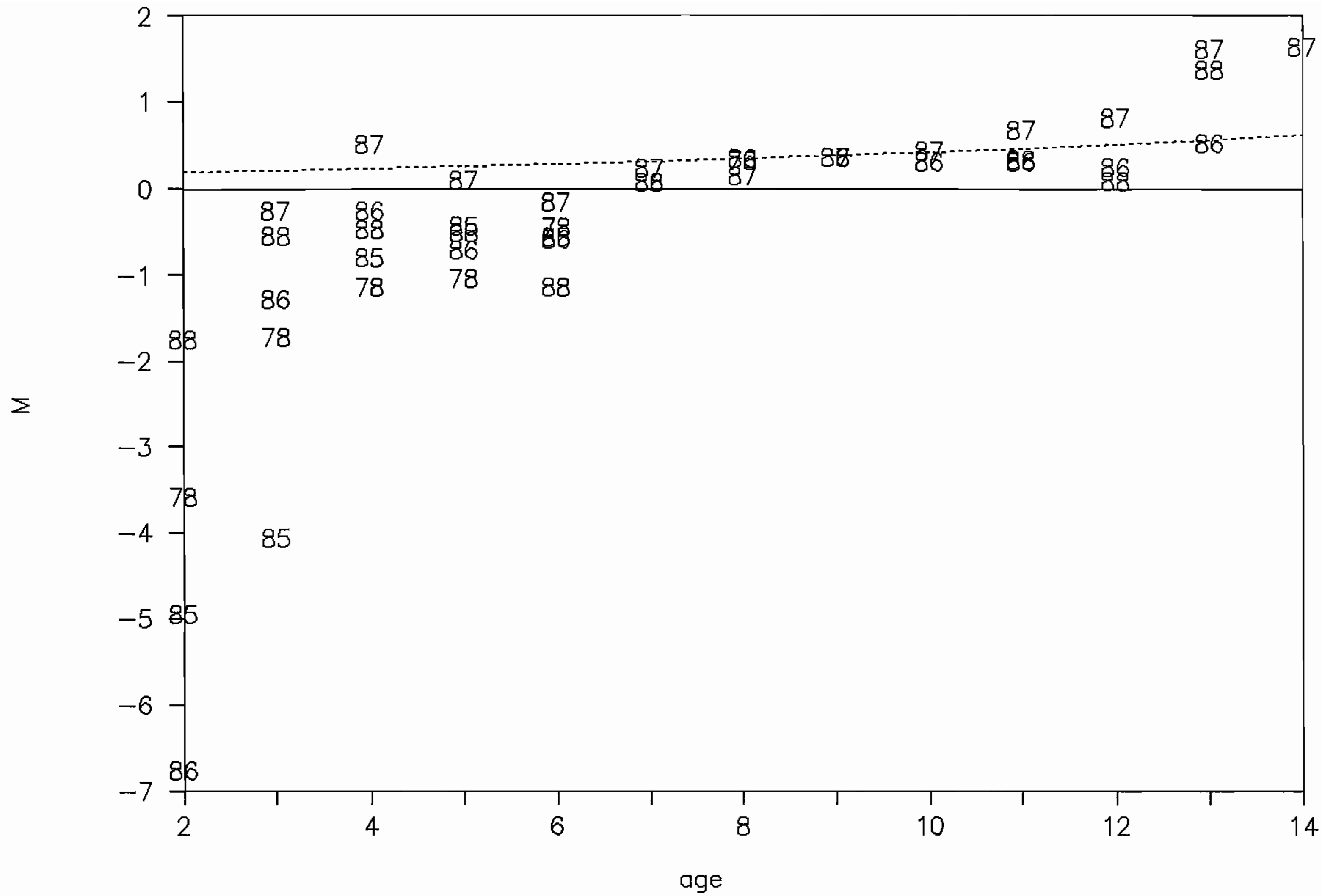

Figure 4. Age specific M from power curve fit through + Z' data.

ACE 6231918

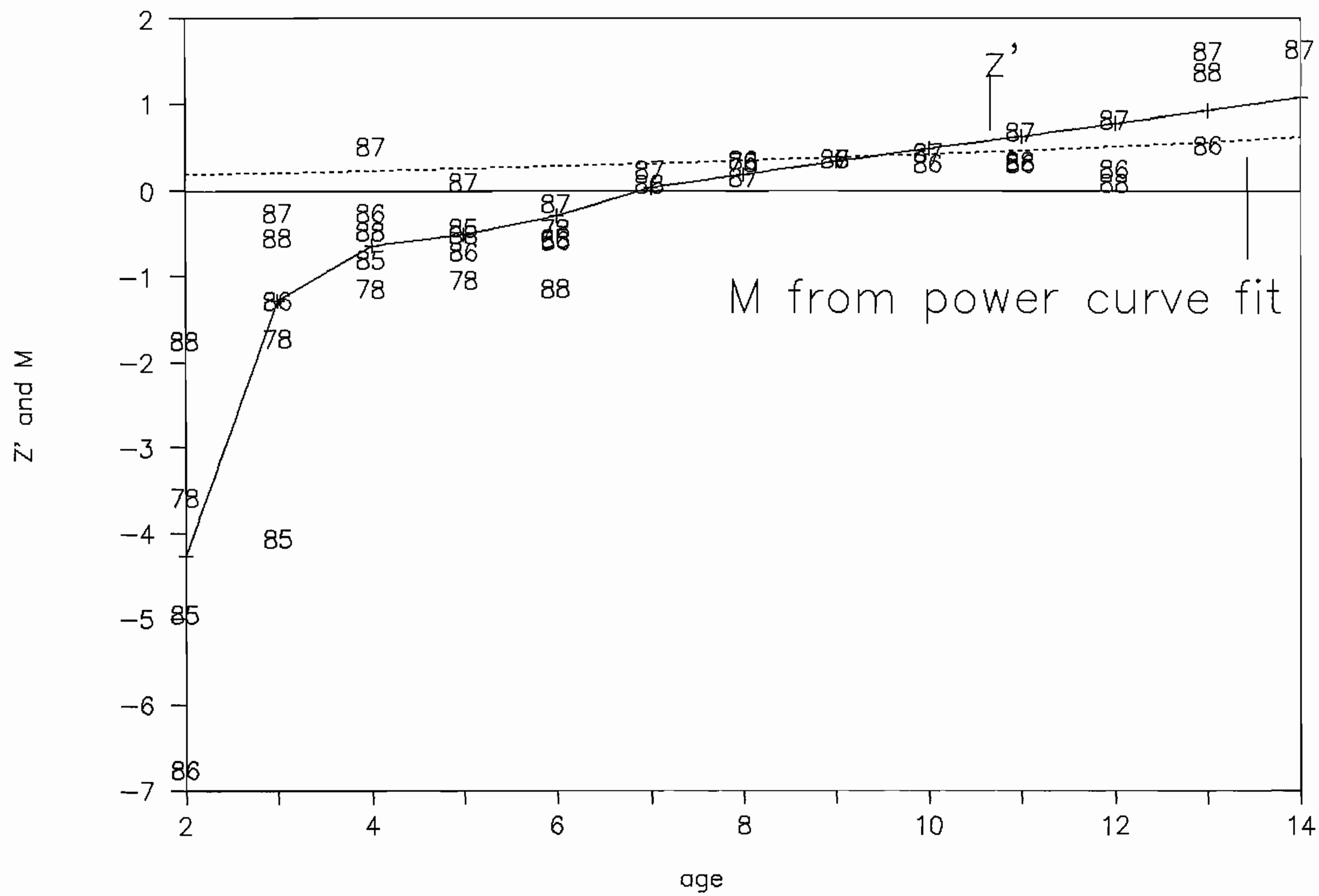

Figure 5. Discrepancy between M and Z' for ages 10 and older.

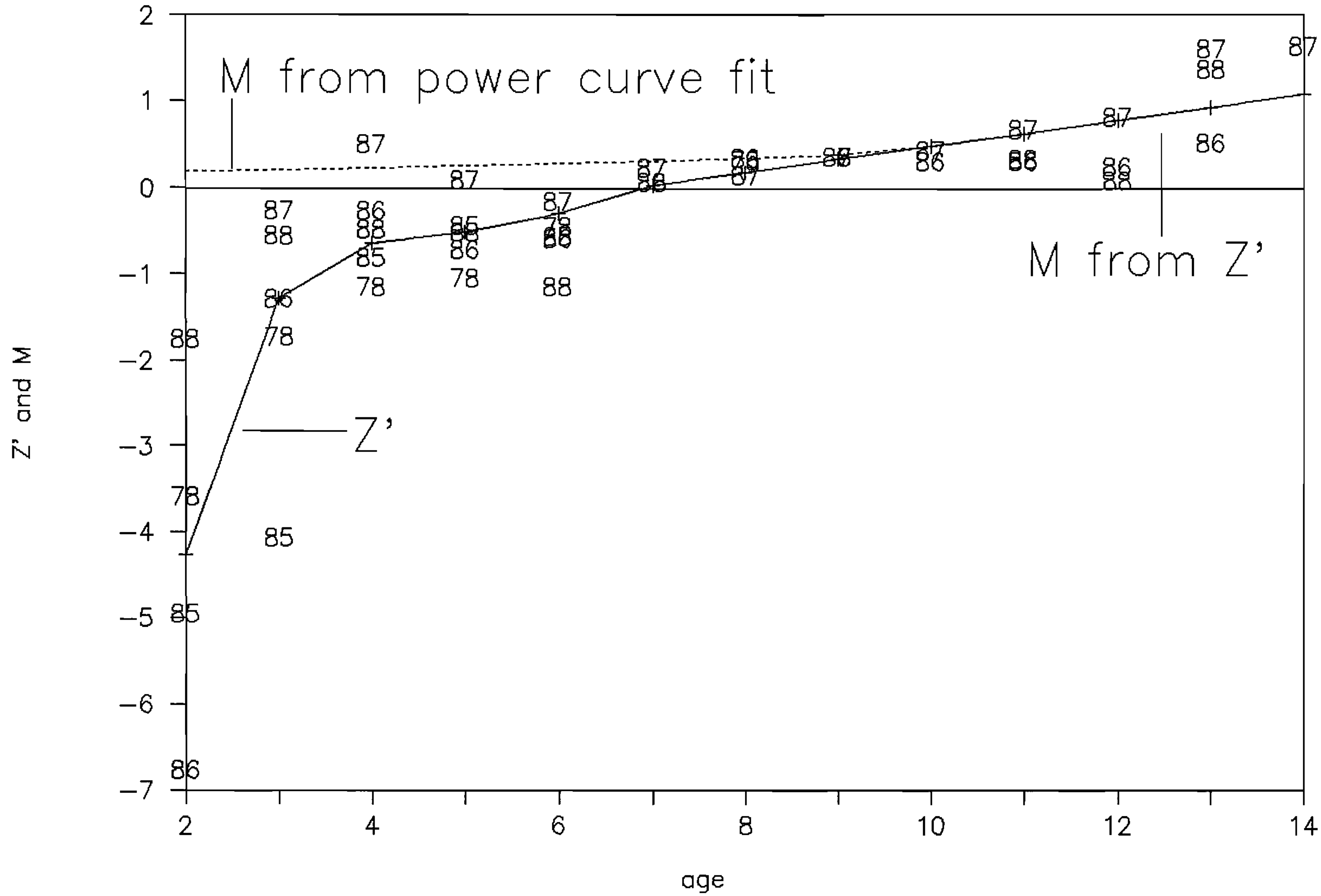

Figure 6. Age specific M approximated from Z' for age 10 and older.

Figure 7. Change in abundance with age.

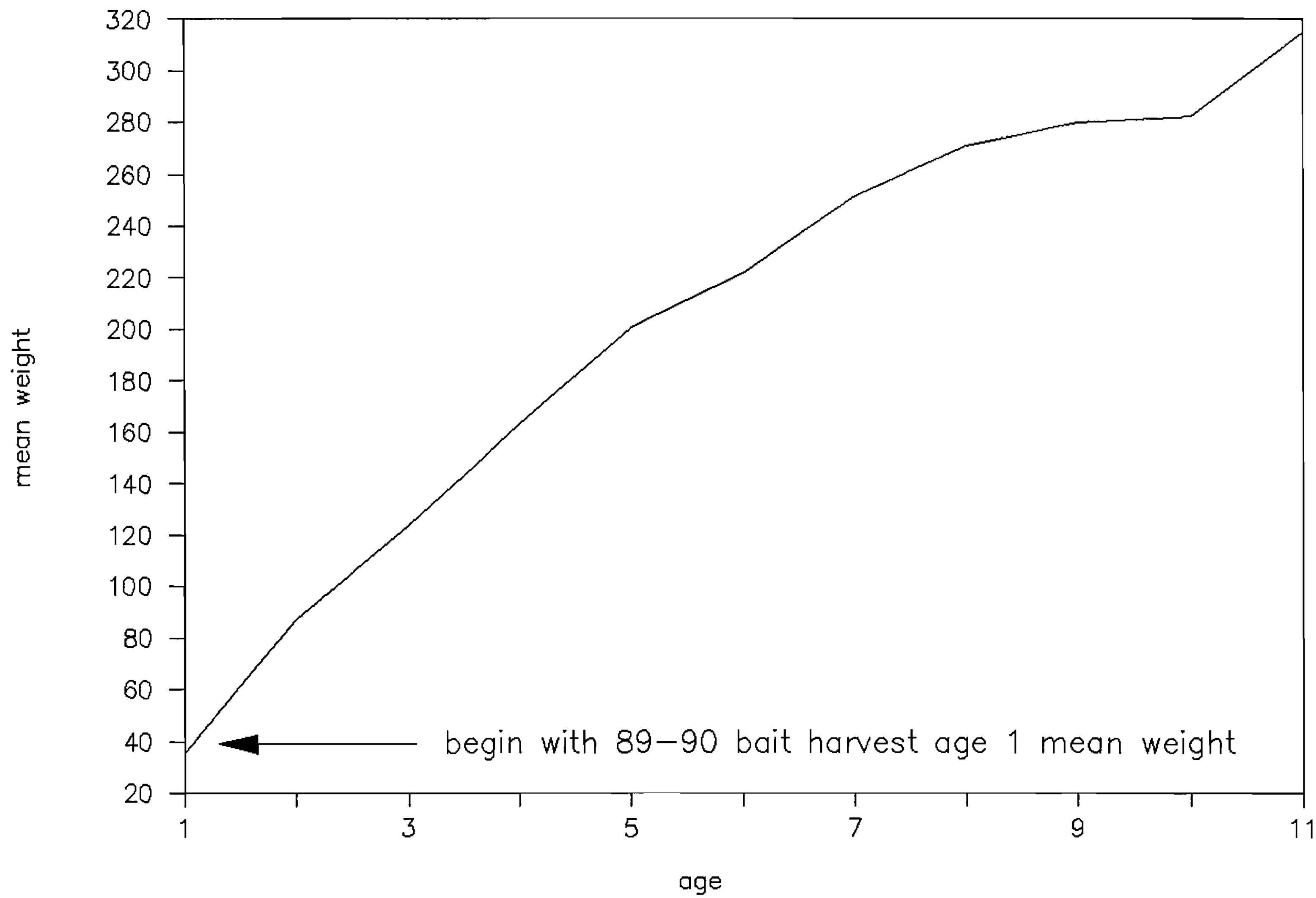

Figure 8. Change in mean weight with age.

ACE 6231922

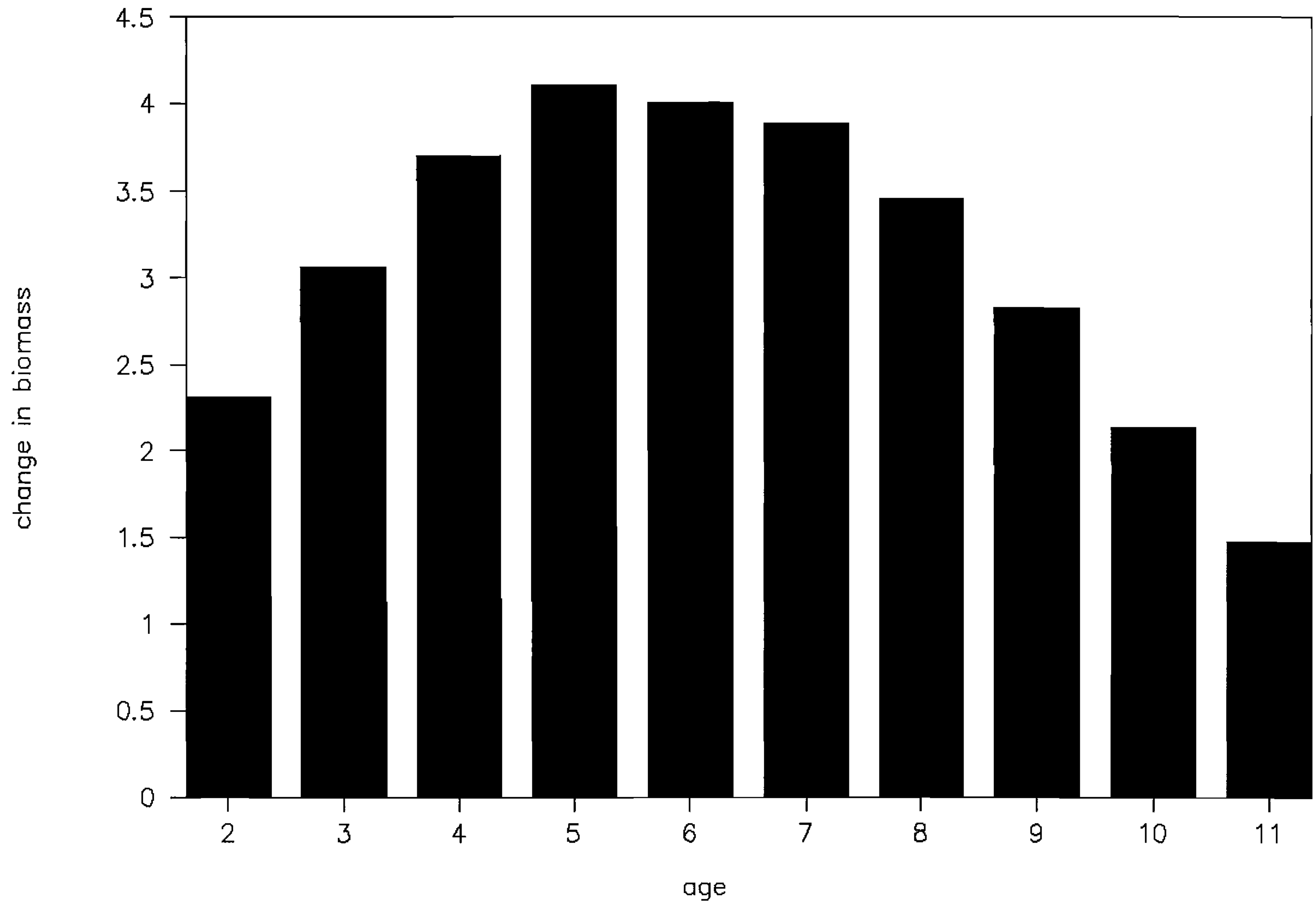

Figure 9. Change in age 1 biomass with age.